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Transmitted herewith for filing is the Patent Application of:

Inventor: Ian M. Holland et al.

For: SIMULATION OF MEMORY-MAPPED I/O

Enclosed are:

- ☒ Patent Specification and Declaration
- ☒ 6 sheets of drawing(s).
- ☒ An assignment of the invention to International Business Machines Corporation (includes Recordation Form Cover Sheet).
- ☐ A certified copy of a application.
- ☐ An associate power of attorney
- ☒ Information Disclosure Statement, PTO 1449 and copies of references.

The filing fee has been calculated as shown below:

For	Number Filed	Number Extra	Rate	Fee
Basic Fee				\$ 770.00
Total Claims	20 - 20	0	x 22 =	\$ - 0 -
Indep. Claims	3 - 3	0	x 80 =	\$ - 0 -
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Respectfully submitted,

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SIMULATION OF MEMORY-MAPPED I/O

TECHNICAL FIELD

5 The present invention relates in general to data processing systems, and in particular, to the loading of data from storage to processor memory.

BACKGROUND INFORMATION

10 Memory-mapped I/O provides advantages in speed of operation of operating system software for loading of data or code from main storage into computer memory (RAM). A problem occurs since some operating systems do not support a memory-mapped file I/O architecture. Certain users of these operating systems have large read only (R/O) files, e.g., databases that have to be read into memory in order to be processed and are immediately paged back out to a paging file or partition by the operating system. This is very slow and requires a
15 considerable amount of disk space.

A solution to this problem would be to have a true memory-mapped I/O file system, but to implement this would require extensive development cost and

time in order to re-program the operating system. Therefore, there is a need in the art for providing an ability for operating systems, which normally do not support memory-mapped I/O file architecture, to provide such a capability.

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SUMMARY OF THE INVENTION

5 The present invention addresses the foregoing need by utilizing a loader that is used for shared libraries, *e.g.*, dynamic link libraries (DLLs) to create memory-mapped I/O which would work on operating systems, that normally do not support memory-mapped file I/O architecture.

10 The present invention uses a converter program to create a simulated DLL (i.e. shared library), which the system loader then loads into the processor memory. This is accomplished by wrapping data with executable code to create a shared library. The system loader will now treat the data as if it were just another code segment. This means that the code is loaded when the virtual page is touched by the application. If the page gets old, then it would be discarded instead of being paged to the paging file. If the page is touched again, it will be re-read from the original file, like memory-mapped I/O.

15 It also has the benefits of performance because it is loaded through the page fault path in the kernel and not the file system API (application program interface) path.

20 In an alternative embodiment of the present invention, compression of the data can be utilized to enable the reading of the compressed data from the hard disk to be performed in a faster and more efficient manner.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the

invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates a normal memory-mapped file layout;

FIGURE 2 illustrates memory-mapping via a system loader;

FIGURE 3 illustrates read only data being converted to a memory-mapped file I/O;

FIGURE 4 illustrates a flow diagram of a standard file I/O API operation;

FIGURE 5 illustrates a flow diagram of a memory-mapped I/O operation;

and

FIGURE 6 illustrates a data processing system configured in accordance with the present invention.

DETAILED DESCRIPTION

5 In the following description, numerous specific details are set forth such as specific word or byte lengths, etc. to provide a thorough understanding of the present invention. However, it will be obvious to those skilled in the art that the present invention may be practiced without such specific details. In other instances, well-known circuits have been shown in block diagram form in order not to obscure the present invention in unnecessary detail. For the most part, details concerning timing considerations and the like have been omitted inasmuch as such details are not necessary to obtain a complete understanding of the present invention and are within the skills of persons of ordinary skill in the relevant art.

10 Refer now to the drawings wherein depicted elements are not necessarily shown to scale and wherein like or similar elements are designated by the same reference numeral through the several views.

15 Referring to FIGURE 1, there is illustrated a process for a memory-mapped file operation. A read only file 102 is stored within a data processing system storage media, such as a hard disk 101. Memory-mapped I/O provides a memory representation of the read only file 102 within the virtual memory 103 associated with an application, which includes the RAM associated with the processor. The memory representation of the read only file 102 is represented as 104 within the virtual memory 103.

20

To create the representation in the memory 104, the operating file system determines how large is the read only file 102, then allocates a block size in the memory 103 for the number of pages that the read only file 102 is going to reside in. The software application 105 is then given a reference pointer to memory, which is in contrast to a standard file I/O API operation (see FIGURE 4) whereby the operating system reads the file into a buffer from the hard disk 101.

The result of this process is that any modifications made to the read only file in memory 104 are reflected back onto the read only file 102 on the hard disk 101 (this is applicable only for read/write files). A page is faulted into the memory block 104 when the page is touched, or referenced. The operating system then reads the exact size for that page out of the file and maps it into the memory 104 at that location.

Not the whole read only file 102 is mapped into the memory block 104 immediately. Instead, there is a range of addresses that are reserved within the virtual memory 103 for the entire size of the read only file 102, but only a portion of the read only file 102 is placed into the memory block 104 at any time.

Referring next to FIGURES 2 and 3, there is illustrated the process of the present invention whereby memory mapping is done via the system loader. What is desired is for a block of data, such as data within a database, to be memory-mapped into the virtual memory 103 as the representation in memory 203, so that the software application 105 can merely use a reference pointer to the

memory 203 instead of reading a file into a buffer from the hard disk 101, which is a less efficient method especially with very large data files.

In order to perform this process in certain operating systems, such as OS/2, Windows 3.X, etc., the data needs to be converted into an executable file, represented in FIGURE 2 as mydata.so/dll 201. Executable files generally include code and accompanying data. In this case, the data portion is optional. The process is performed by taking a read only file 301 and putting it through a code converter 302, which is a tool that wrappers the read only data with code headers and records in order to make the operating system loader 202 believe that the read only file is executable code. The system loader 202 then believes that the read only file is executable code and performs a memory-map operation to memory-map the read only file as the image representation in memory 203. The software application 105 is then given a reference pointer to the memory 203 in order to access the read only file.

The result of the foregoing operation is that the read only file is converted into an executable/shared library file 305, such as a DLL executable. The system loader 202 looks at the read only file as just another DLL and maps it right into memory 103. An option is for the R/O file to be passed through a tool in steps 303-304 that generates an object file and then generates an executable or shared libraries using the object file as an input into a link editor or generates the executable or shared library directly skipping the intermediate step..

The system loader 202 may be "fooled" into believing that the read only file on the hard disk 101 is executable code by the mere switching of a bit within a predesignated field. The system loader then just looks for the bit to determine whether or not the mydata.so/dll file is executable code or not.

5 The tool that performs the code conversion is one that can be programmed using the standard tools within the particular operating system platform. Such a tool can be found within the Tool Interface Standards, Portable Format Specification Version 1.0, TIS Committee, February 1993 and other standard documents for specified platforms.

10 One of the advantages of using the memory-mapped I/O method is that it is faster than standard file I/O API operations. With the standard API operations, the file system has to call a consecutive series of APIs to the kernel, which usually has to perform several ring transitions which are very costly. So therefore, every time a file is opened, a ring transition is performed, and when a read is performed,
15 another ring transition is performed.

20 FIGURE 4 illustrates the process for a standard file I/O API operation. In step 401, an application may open a file. The operating system loads the path name where the file is going to be and opens the file. On opening the file, there is no data in memory. Then in step 402, the operating system has to create a buffer to read the file into. This may be accomplished by some type of memory allocation routine from the kernel which provides a chunk of memory. Then, in step 403, an "x" number of bytes is read from the file into the buffer. In step 404,

the bytes are processed in the read buffer. This is where the application uses the data it read from the file. In step 405, it is determined whether or not the end of the file has been reached. If not, then in step 406, if the buffer is too small and the end of the file has not been reached, then reads are performed until the end of the file and the process loops back to step 403. However, if the end of the file has been reached in step 405, then the process proceeds to step 407 to free the buffer and then close the file in step 408.

In contrast, FIGURE 5 illustrates a memory-mapped I/O operation. In step 501, a file is memory-mapped. In step 502, the bytes are processed within the memory 103 by merely referencing a pointer to the memory that was returned in the initial map call. And in step 503, the memory-mapped data will be freed up by calling the appropriate unmap API, or it will automatically be freed when the application is terminated by the user. With the memory-mapped I/O, a memory-mapped API is called and the application is returned a pointer that points to a portion of the memory representation. As a result, it could be easily seen that the process illustrated in FIGURE 5 is much simpler, and faster than the process illustrated in FIGURE 4. All that is needed with the memory-mapped I/O process for the application to read the data is to de-reference that memory and point to that memory location and the information is then provided. This is performed automatically by the operating system loading semantics.

A representative hardware environment for practicing the present invention is depicted in FIGURE 6, which illustrates a typical hardware configuration of

workstation 613 in accordance with the subject invention having central processing unit (CPU) 610, such as a conventional microprocessor, and a number of other units interconnected via system bus 612. Workstation 613 includes random access memory (RAM) 614, read only memory (ROM) 616, and input/output (I/O) adapter 618 for connecting peripheral devices such as disk units 620 and tape drives 640 to bus 612, user interface adapter 622 for connecting keyboard 624, mouse 626, speaker 628, microphone 632, and/or other user interface devices such as a touch screen device (not shown) to bus 612, communication adapter 634 for connecting workstation 613 to a data processing network, and display adapter 636 for connecting bus 612 to display device 638. CPU 610 may include other circuitry not shown herein, which will include circuitry commonly found within a microprocessor, e.g., execution unit, bus interface unit, arithmetic logic unit, etc. CPU 610 may also reside on a single integrated circuit.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

- 1 1. A method comprising the steps of:
2 converting a read only file into an executable file; and
3 memory-mapping the converted file into memory.
- 1 2. The method as recited in claim 1, wherein the memory is virtual memory
2 associated with an application running in a processor.
- 1 3. The method as recited in claim 2, wherein the converted file is
2 memory-mapped from system storage by an operating system loader.
- 1 4. The method as recited in claim 3, wherein the converted file appears to the
2 operating system loader as a shared library file.
- 1 5. The method as recited in claim 3, wherein the read only file is a database
2 file.
- 1 6. The method as recited in claim 3, wherein the converting step further
2 comprises the step of wrapping the read only file with executable code.

- 1 7. A data processing system comprising:
2 circuitry for converting a read only file into an executable file; and
3 circuitry for memory-mapping the converted file into memory.
- 1 8. The data processing system as recited in claim 7, wherein the memory is
2 virtual memory associated with an application running in a processor.
- 1 9. The data processing system as recited in claim 7, wherein the converted file
2 is memory-mapped from system storage by an operating system loader.
- 1 10. The data processing system as recited in claim 9, wherein the converted file
2 appears to the operating system loader as a shared library file.
- 1 11. The data processing system as recited in claim 7, wherein the read only file
2 is a database file.
- 1 12. The data processing system as recited in claim 7, wherein the converting
2 circuitry further comprises circuitry for wrapping the read only file with executable
3 code.

1 13. A computer program tool adaptable for storage in a storage medium,
2 comprising:

3 program code for converting a read only file into an executable file; and
4 program code for memory-mapping the converted file into memory.

1 14. The computer program tool as recited in claim 13, wherein the memory is
2 virtual memory associated with an application running in a processor.

1 15. The computer program tool as recited in claim 14, wherein the converted
2 file is memory-mapped from system storage by an operating system loader.

1 16. The computer program tool as recited in claim 15, wherein the converted
2 file appears to the operating system loader as a shared library file.

1 17. The computer program tool as recited in claim 15, wherein the read only
2 file is a database file.

1 18. The computer program tool as recited in claim 14, wherein the converting
2 program code further comprises program code for wrapping the read only file with
3 executable code.

1 20. The computer program tool as recited in claim 15, wherein the read only
2 file is an audio file.

Variable	Mean	SD	Min	Max
Age	35.2	12.5	18	65
Gender	Male	10.5	0	20
Marital status	Married	15.2	0	25
Education	High school	12.5	0	20
Occupation	Unemployed	18.5	0	25
Income	\$15,000	\$10,000	\$0	\$40,000
Health status	Good	10.5	0	20
Smoking status	Non-smoker	12.5	0	20
Alcohol consumption	Occasional	15.2	0	25
Exercise frequency	Weekly	18.5	0	25
Stress level	Low	10.5	0	20
Sleep quality	Good	12.5	0	20
Appetite	Normal	15.2	0	25
Weight change	Stable	18.5	0	25
Blood pressure	Normal	10.5	0	20
Blood sugar	Normal	12.5	0	20
Cholesterol	Normal	15.2	0	25
Heart rate	Normal	18.5	0	25
Respiratory rate	Normal	10.5	0	20
Oxygen saturation	Normal	12.5	0	20
White blood cell count	Normal	15.2	0	25
Hemoglobin	Normal	18.5	0	25
Hematocrit	Normal	10.5	0	20
Platelet count	Normal	12.5	0	20
Prothrombin time	Normal	15.2	0	25
Partial thromboplastin time	Normal	18.5	0	25
Fibrinogen	Normal	10.5	0	20
D-dimer	Normal	12.5	0	20
C-reactive protein	Normal	15.2	0	25
Erythrocyte sedimentation rate	Normal	18.5	0	25
Urea nitrogen	Normal	10.5	0	20
Creatinine	Normal	12.5	0	20
Bilirubin	Normal	15.2	0	25
Aspartate aminotransferase	Normal	18.5	0	25
Alanine aminotransferase	Normal	10.5	0	20
Lactate dehydrogenase	Normal	12.5	0	20
Prothrombin time	Normal	15.2	0	25
Partial thromboplastin time	Normal	18.5	0	25
Fibrinogen	Normal	10.5	0	20
D-dimer	Normal	12.5	0	20
C-reactive protein	Normal	15.2	0	25
Erythrocyte sedimentation rate	Normal	18.5	0	25
Urea nitrogen	Normal	10.5	0	20
Creatinine	Normal	12.5	0	20
Bilirubin	Normal	15.2	0	25
Aspartate aminotransferase	Normal	18.5	0	25
Alanine aminotransferase	Normal	10.5	0	20
Lactate dehydrogenase	Normal	12.5	0	20
Prothrombin time	Normal	15.2	0	25
Partial thromboplastin time	Normal	18.5	0	25
Fibrinogen	Normal	10.5	0	20
D-dimer	Normal	12.5	0	20
C-reactive protein	Normal	15.2	0	25
Erythrocyte sedimentation rate	Normal	18.5	0	25
Urea nitrogen	Normal	10.5	0	20
Creatinine	Normal	12.5	0	20
Bilirubin	Normal	15.2	0	25
Aspartate aminotransferase	Normal	18.5	0	25
Alanine aminotransferase	Normal	10.5	0	20
Lactate dehydrogenase	Normal	12.5	0	20
Prothrombin time	Normal	15.2	0	25
Partial thromboplastin time	Normal	18.5	0	25
Fibrinogen	Normal	10.5	0	20
D-dimer	Normal	12.5	0	20
C-reactive protein	Normal	15.2	0	25
Erythrocyte sedimentation rate	Normal	18.5	0	25
Urea nitrogen	Normal	10.5	0	20
Creatinine	Normal	12.5	0	20
Bilirubin	Normal	15.2	0	25
Aspartate aminotransferase	Normal	18.5	0	25
Alanine aminotransferase	Normal	10.5	0	20
Lactate dehydrogenase	Normal	12.5	0	20
Prothrombin time	Normal	15.2	0	25
Partial thromboplastin time	Normal	18.5	0	25
Fibrinogen	Normal	10.5	0	20
D-dimer	Normal	12.5	0	20
C-reactive protein	Normal	15.2	0	25
Erythrocyte sedimentation rate	Normal	18.5	0	25
Urea nitrogen	Normal	10.5	0	20
Creatinine	Normal	12.5	0	20
Bilirubin	Normal	15.2	0	25
Aspartate aminotransferase	Normal	18.5	0	25
Alanine aminotransferase				

SIMULATION OF MEMORY-MAPPED I/O

ABSTRACT OF THE DISCLOSURE

5 A converter program creates a simulated executable portion of code so that the operating system loader believes that a read only file of data consists of executable code and thereby memory-maps the read only file into virtual memory from storage. The result is that a large database may be memory-mapped into the processor virtual memory instead of the file having to be opened using standard file application program interface operations.

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FIG. 1

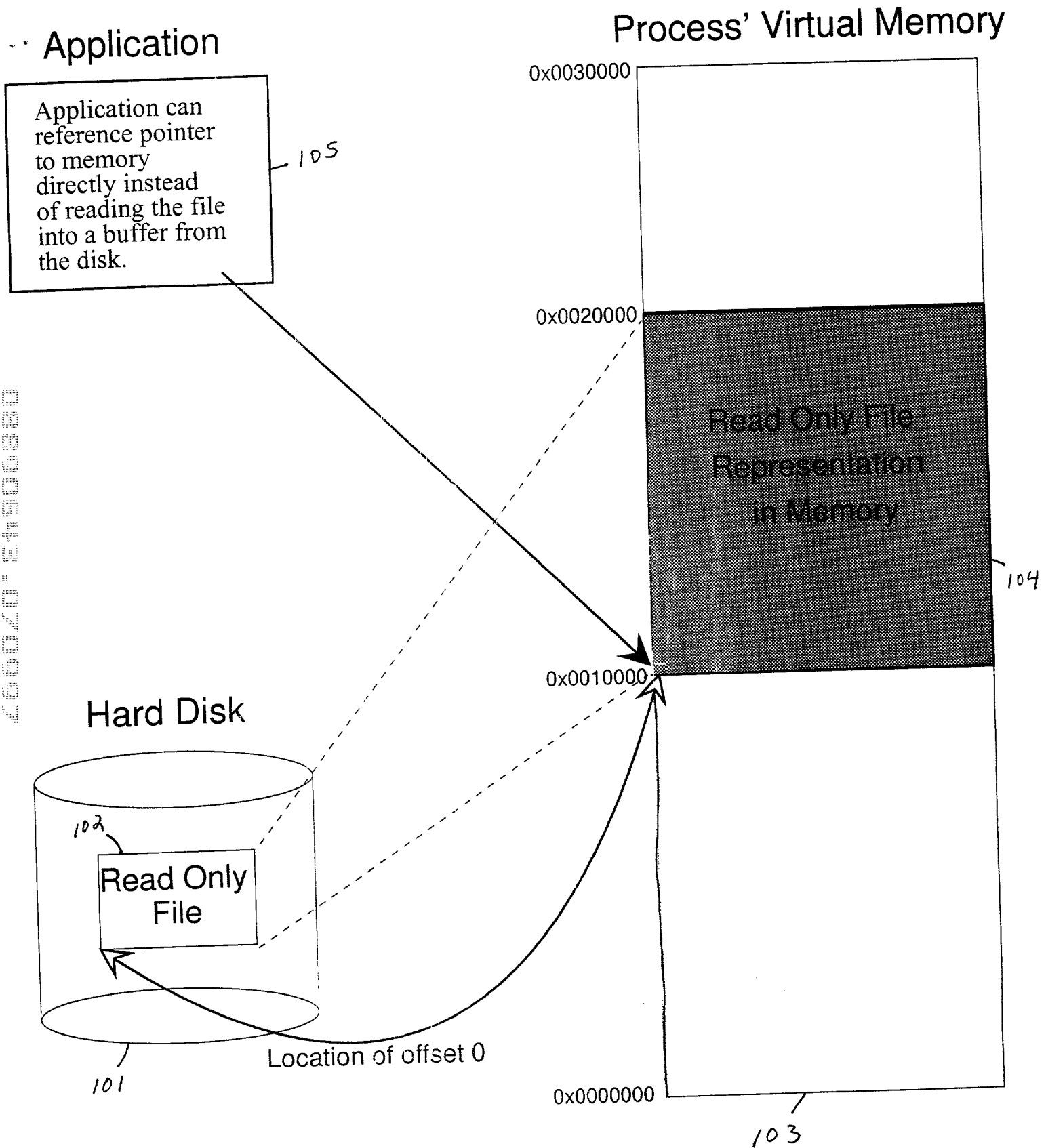
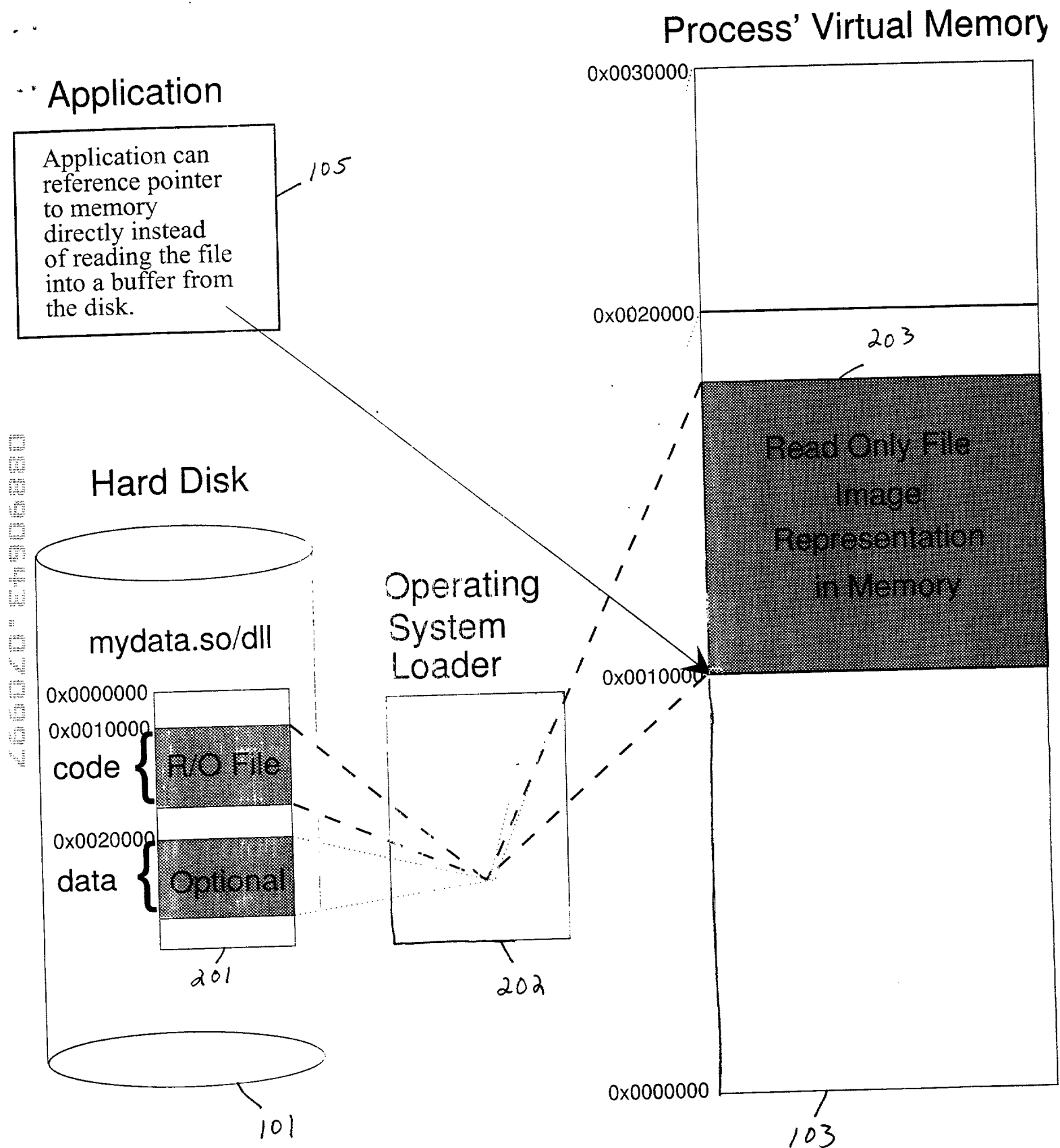


FIG. 2



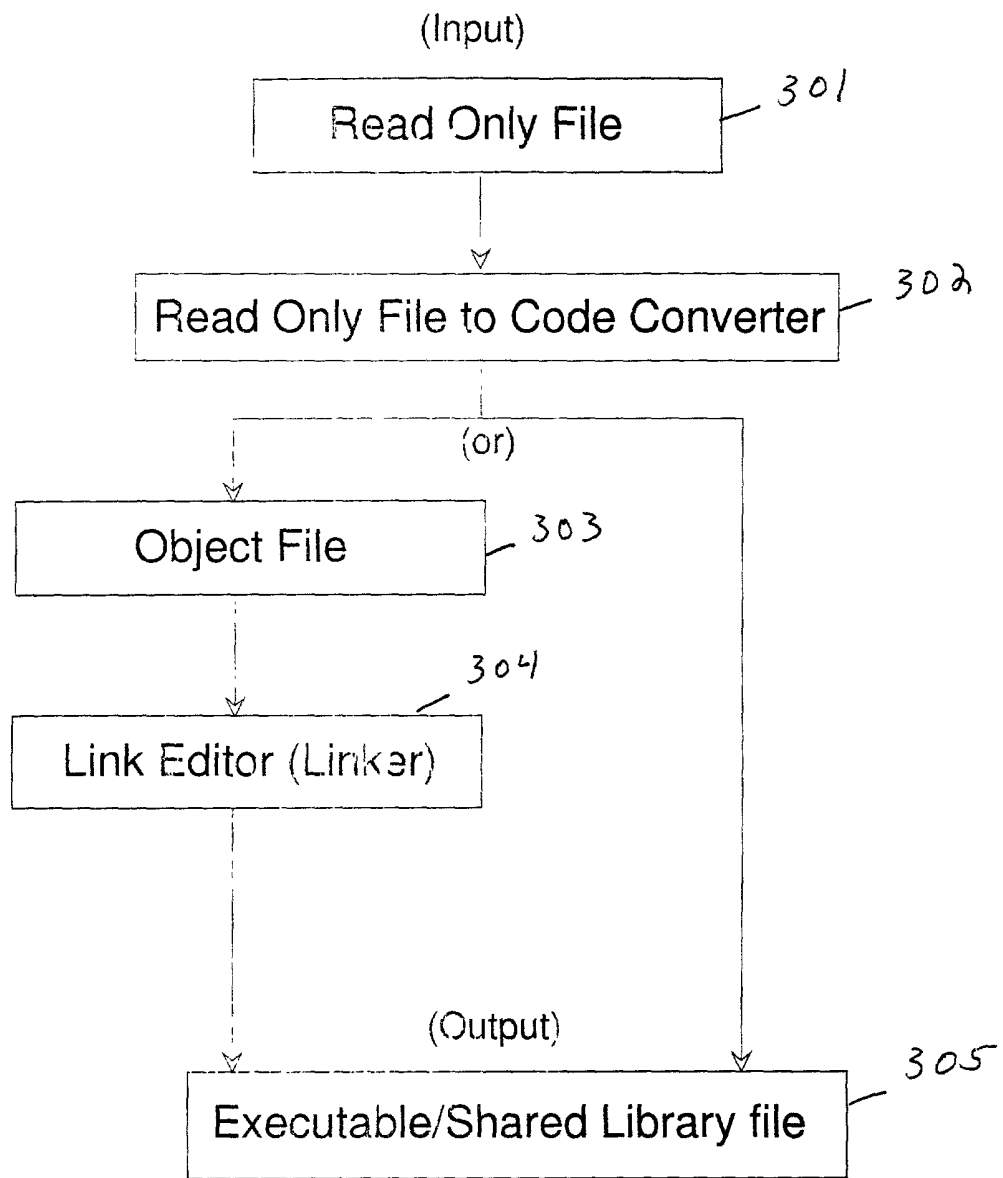


FIG. 3

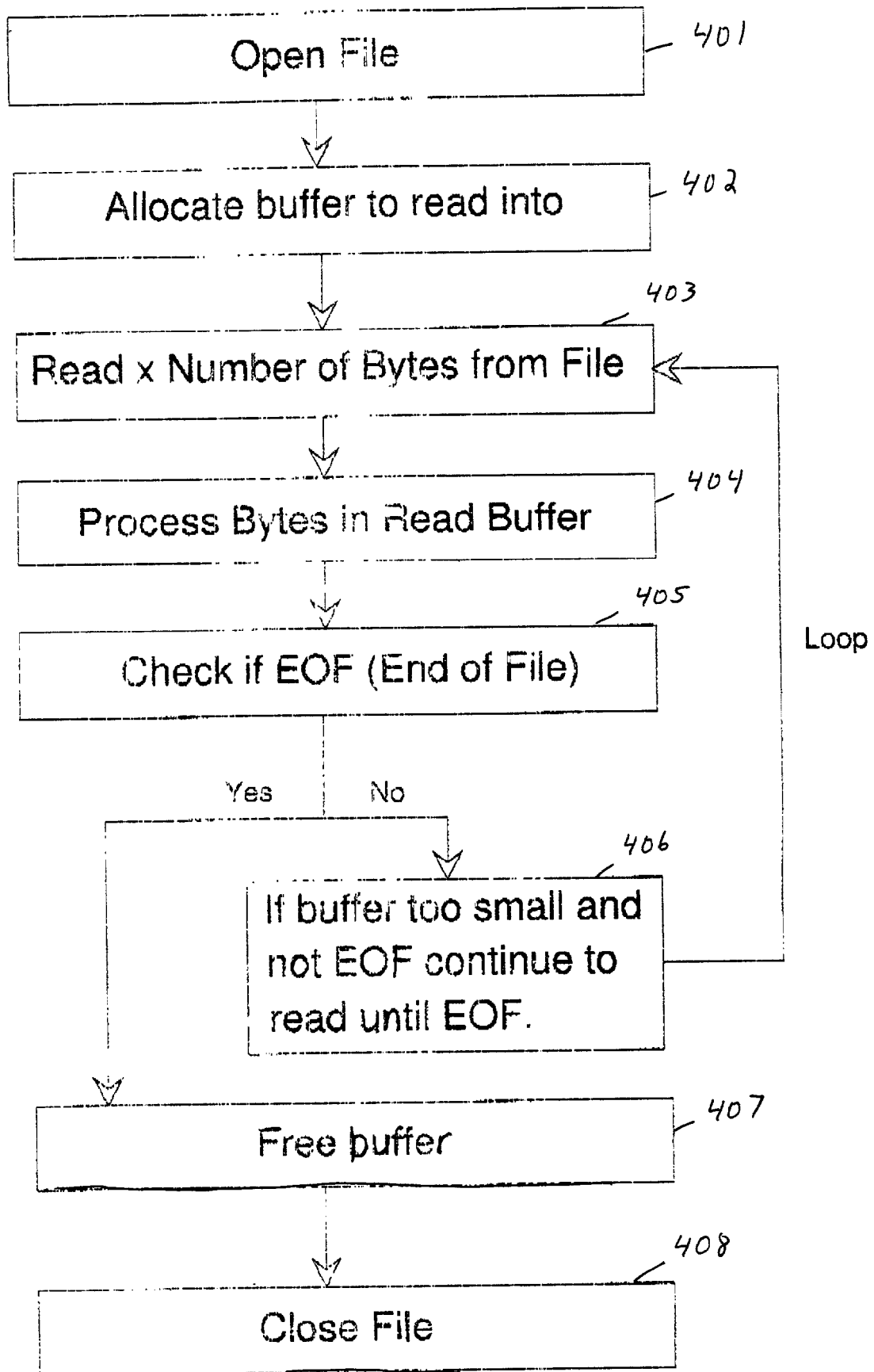


FIG. 4

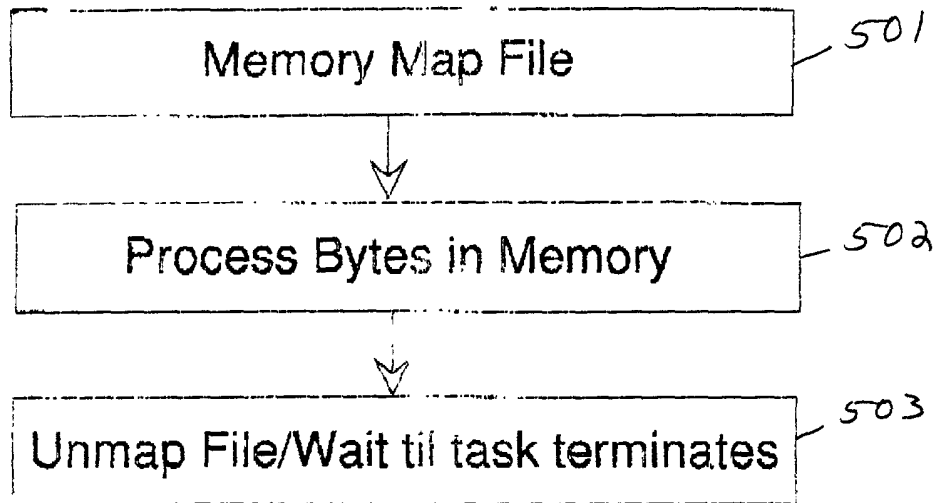


FIG. 5

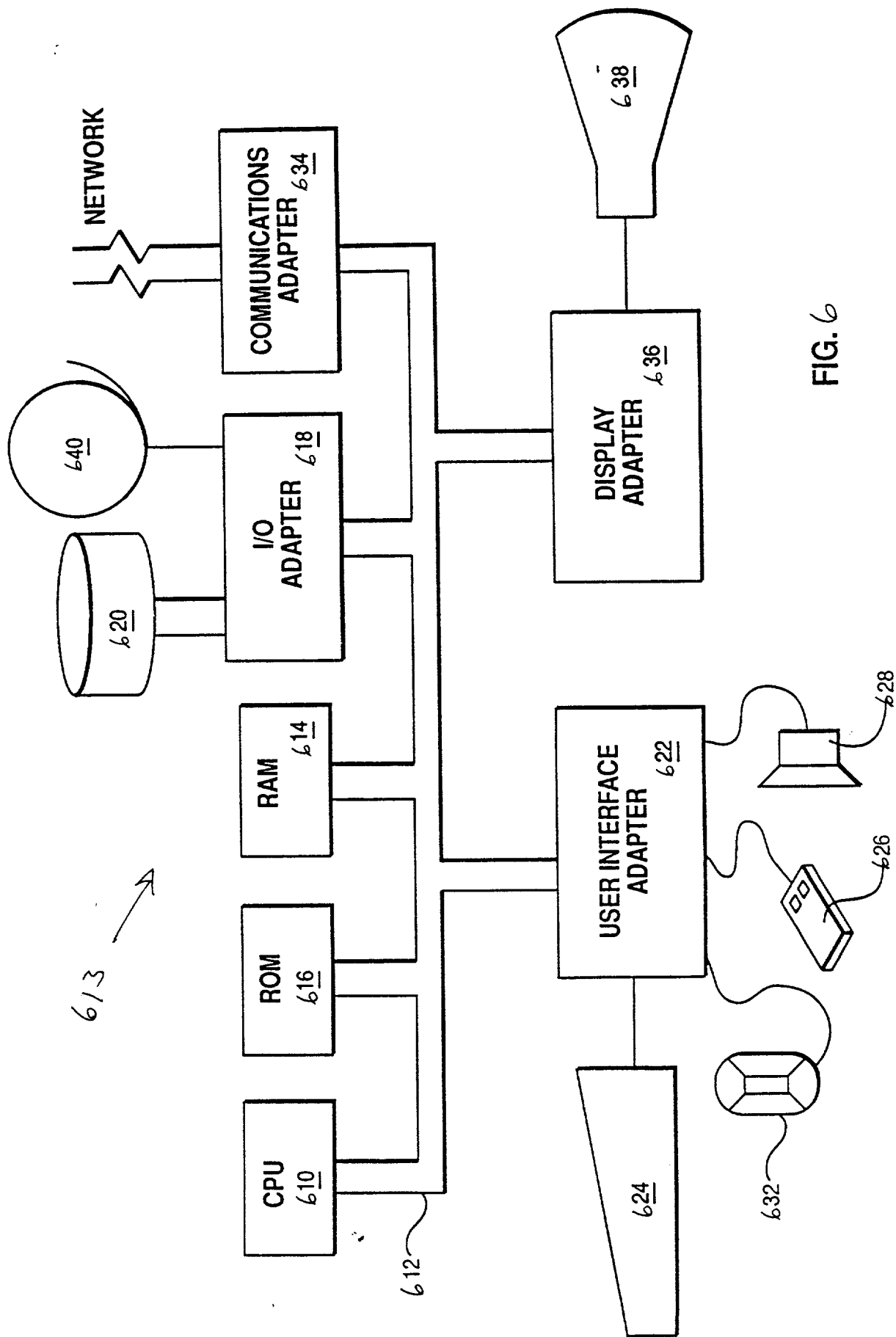


FIG. 6

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SIMULATION OF MEMORY-MAPPED I/O

the specification of which (check one)

- ☒ is attached hereto.
- ☐ was filed on _____
as Application Serial No. _____
and was amended on _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

Priority Claimed

(Number)

(Country)

(Day/Month/Year)

☐ Yes ☐ No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial #)

(Filing Date)

(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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